Drake Greenside Two, Suite 200
2525 Redwing
Ft Collins, Colorado 80526
(303) 226-6003

FINAL TECHNICAL REPORT

to

National Aeronautics and Space Administration

Langley Research Center

for

Contract NAG-1-150

RADIATION BUDGET MEASUREMENT/MODEL INTERFACE

Thomas H. Vonder Haar, Principal Investigator

With Contributions by:

Paul Ciesielski
David Randel
Duane Stevens
Thomas Vonder Haar

For the Period: February, 1981 to November, 1982

G. Louis Smith, Technical Monitor

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Research Institute of Colorado

CONTENTS

SUMMARY

This final report includes research results from the period February, 1981 through Nomember, 1982.

Two new results combine to form the final portion of our work. They are the work by Hanna (1982) and Stevens to successfully test and demonstrate a low-order spectral climate model and the work by Ciesielski et al. (1983) to combine and test the new radiation budget results from NIMBUS-7 with earlier satellite measurements. Together, the two related activities bring us to a new research plateau and set the stage for future research on radiation budget measurement/model interfacing. Such combination of results will lead to new aplications of satellite data to climate problems. The objectives of our research under the present contract are therefore satisfied.

Additional research reported herein includes the compilation and documentation of the radiation budget data set at Colorado State University and the definition of climate-related experiments suggested after lengthy analysis of the satellite radiation budget experiments. Since both the primary studies noted above were supported, in part, under other auspices we include the abstracts of the related publications as an appendix.

1.0 Improved Earth Radiation Budget Data Sets

Since the first satellite radiation budget experiment on Explorer VII in 1959 (Suomi, 1959), we have obtained an increasingly detailed and accurate depiction of the energy exchange between earth and space. For climate study purposes a choice must be made when using the radiation budget data for a specific study. The choice depends upon the goals of the line of climate inquiry, which then dictates whether to use:

a) the longest (most extensive temporal) satellite data set

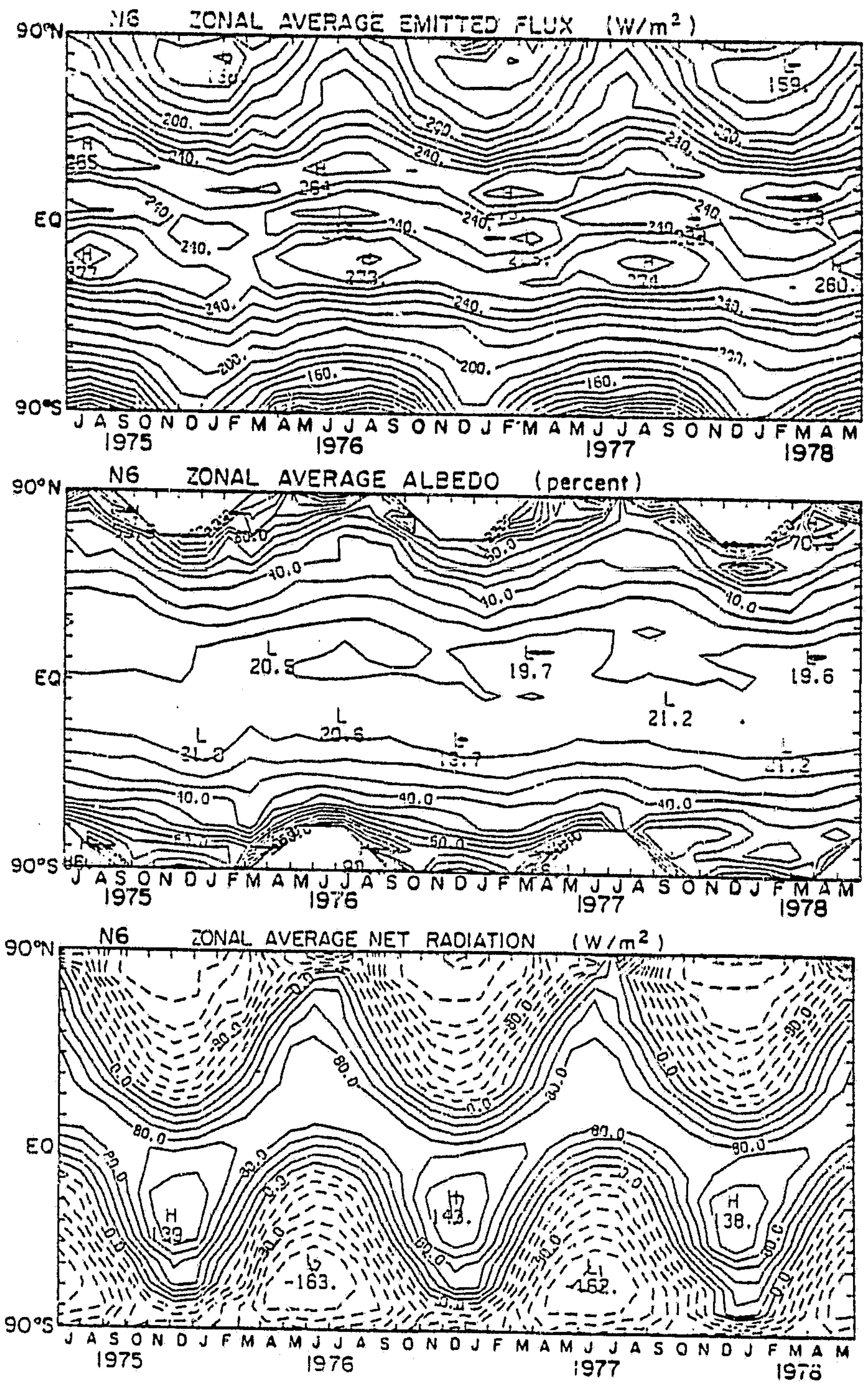
or b) the most accurate and consistent "sample" of the seasonal (or monthly) radiation fields from Earth.

Of course, since most of the existing data were obtained from wide field-of-view sensors, a consideration of the spatial resolution requirements of the climate study must also be made.

In order to assist the climate modeler we have prepared a special report under this contract (Ciesielski and Vonder Haar, 1982) with an accompanying data tape. See Appendix 1 for details. The report and tape were prepared to aid our contract work and also in response to requests of climate scientists around the nation and the world. A copy of the tape has been provided to the technical monitor and to several other research groups. An example of the analysis of a field of data from the archive tape is shown in Figure 1. In the figure, nearly three annual cycles of satellite radiation budget measurements are displayed.

The new radiation budget results were obtained after considerable study of data processing and analysis methods in collaboration with NIMBUS project scientists and engineers (Vonder Haar _et al._, 1981).

FIGURE 1



Contour plots of time variation of zonal mean emitted exitance, albedo, and net radiation from July, 1975 to May, 1978 (from NIMBUS 6 data). (after Ciesielski, et al., 1983)

Our preliminary analysis of NIMBUS-6 data has revealed some interesting interannual differences in the earth's radiation budget. Figures 2 and 3 show the interannual differences in the zonal means fluxes of emitted and net radiation, respectively, for the December-January period. Especially striking in the figures are the differences in the emitted flux between the 75/76 and 76/77 periods. For example, the emitted flux in December 76 and January 77 was between 10-40 watts per square meter larger at high latitudes (65°N - 85°N) and approximately 15 watts per square meter less at mid-latitudes (35°N - 55°N) in comparison to December 75 - January 76 period. It is also of interest to note that the December 76 - January 77 period was characterized by strong and persistent atmospheric blocking patterns in the Northern Hemisphere. The economic dislocation in the United States was substantial.

Under such blocking conditions one might expect an increase in the meridional circulation allowing anomalous amounts of warm air to be advected into higher latitudes, and in turn, increased longwave emission at these latitudes. Of course, the generally cloud-free conditions under the high latitude ridge would also add to the increased longwave emission. The weak solar radiation at high latitudes in winter cannot compensate for the increased IR loss. Conversely, at mid-latitudes, an increase in the cold air advection associated with the blocking flow would result in decreased longwave emission from both cooler air and the increased cloudiness. The enhanced net radiation gradient (e.g., 30° to 80° in Figure 3) would seem to increase the required poleward energy transport by the ocean-atmosphere

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Figure 2

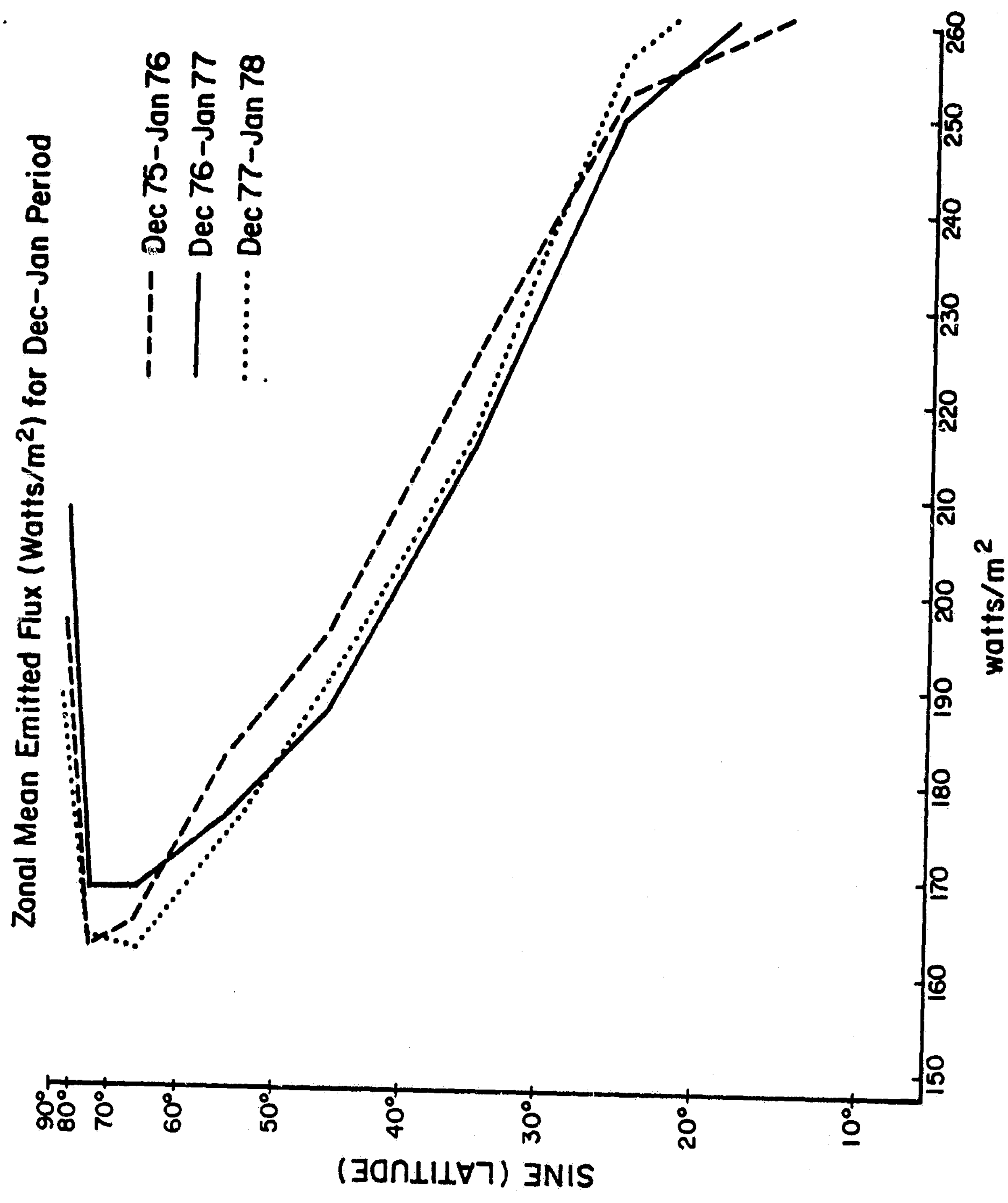

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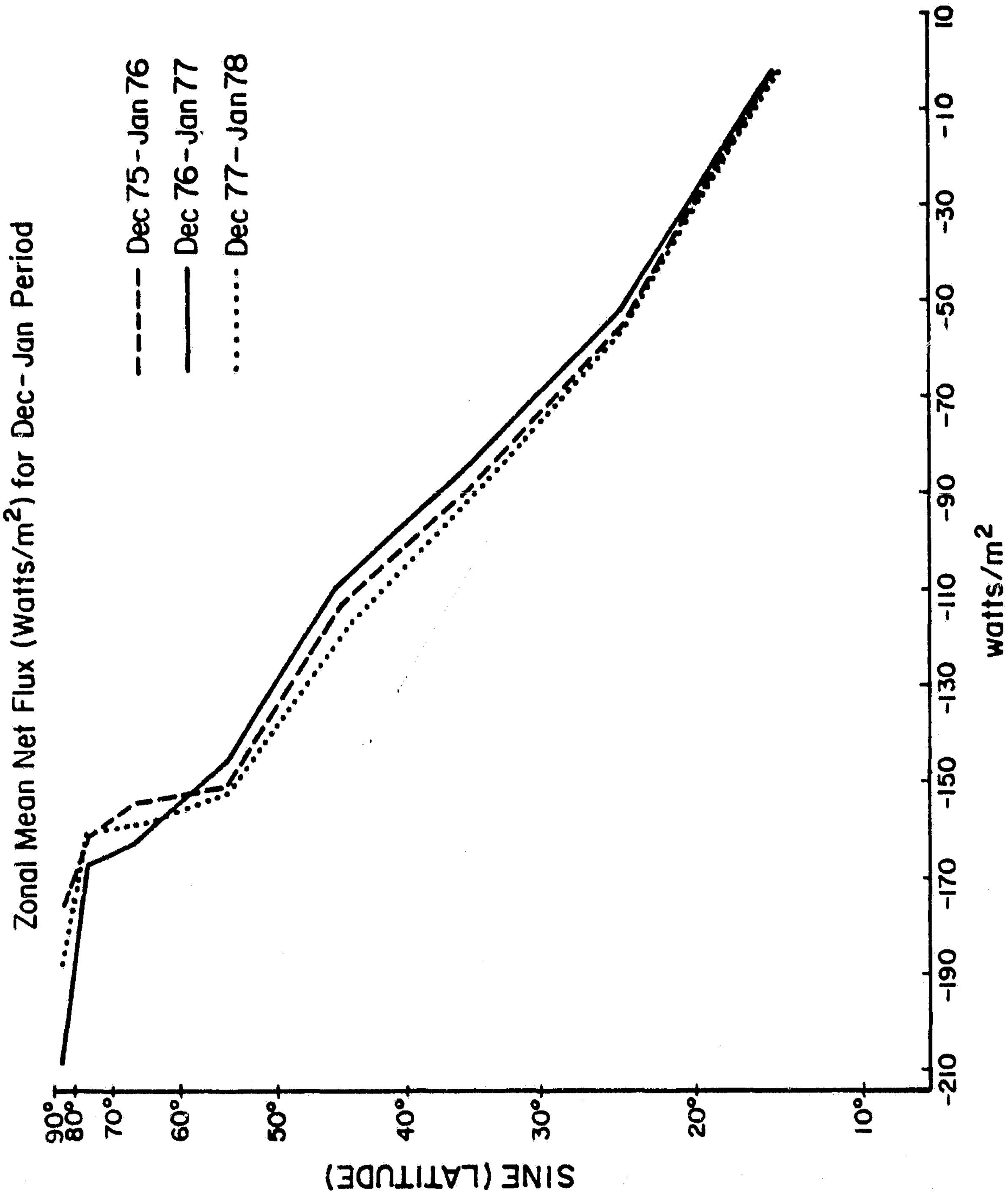
Figure 3



system during the blocking situation. It remains for specific model studies to ascertain whether this radiation forcing causes positive or negative feedback into the blocking situation.

Through an application of the thermal wind equation, we know that the thickness of an atmospheric layer is proportional to the mean temperature of that layer. In view of this fact, one can roughly surmise from Figure 4 (taken from Vols. 104 and 105, Monthly Weather Review) the temperature differences at high and mid-latitudes that existed between the 75/76 and 76/77 winter seasons.

FIGURE 4

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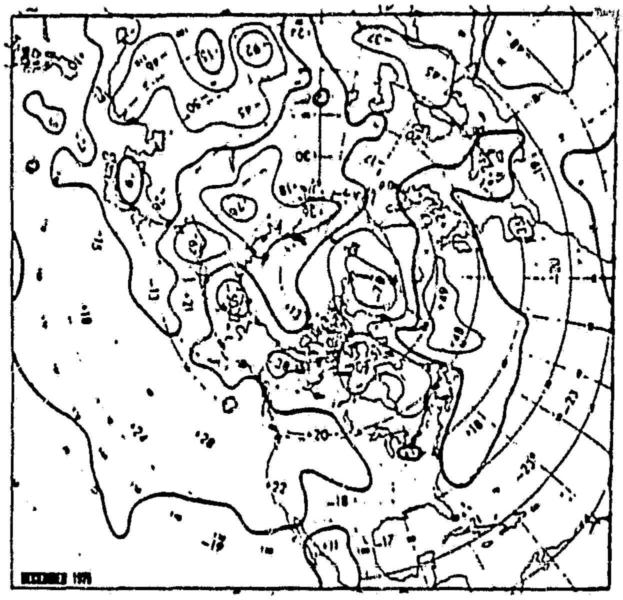
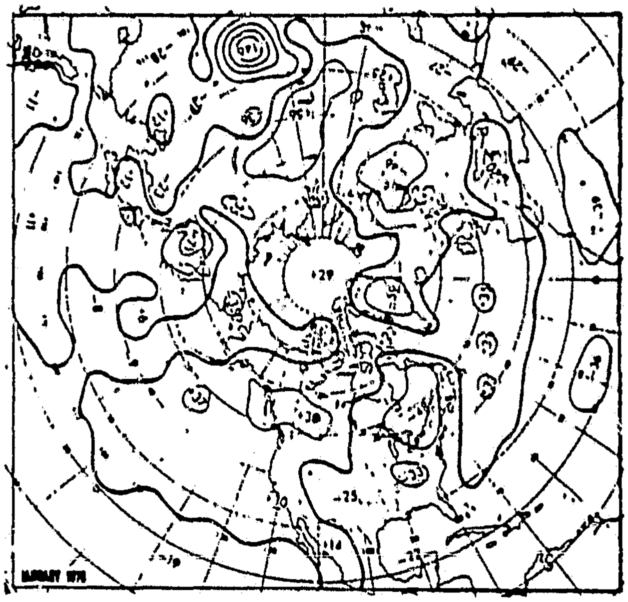
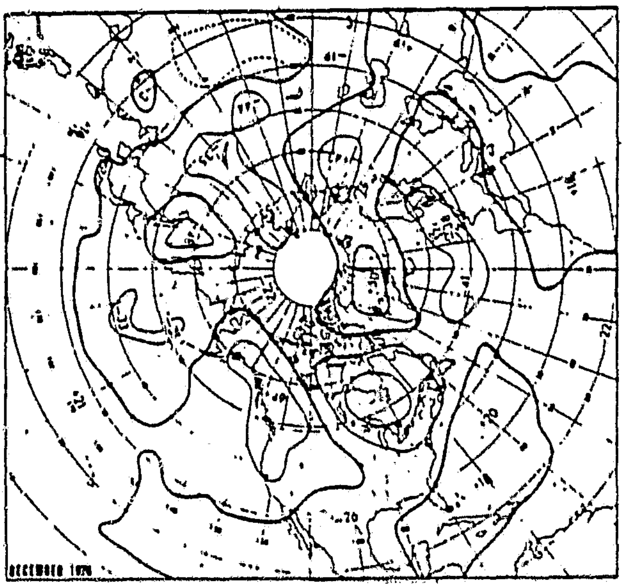


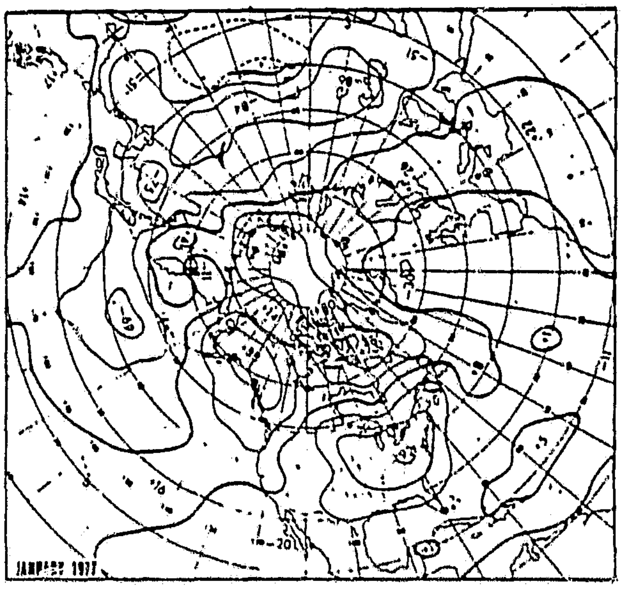
Departure from normal of mean 1000 to 700 mb thickness (m) for December 1975.



Departure from normal of mean 1000 to 700 mb thickness (m) for January 1976.



Departure from normal of mean 1000–700 mb thickness (m) for December 1976.



Departure from normal of mean 1000–700 mb thickness (m) for January 1977.

(from Mon. Wea. Rev., Vols. 104 and 105)

2.0 Numerical Model Experiment Definition and Tests

Due to the large differences in atmospheric circulation and characteristics of the radiation budget between the two winter seasons mentioned above and observed by the radiation budget sensors, we suggest the following numerical experiment. By prescribing the diabatic forcing for the "linear balance" numerical model as given in part by the earth's radiation budget, we suggest simulation of the circulation patterns corresponding to each winter season. Of particular interest will be the amplitude and position of the standing eddies which result from each winter's forcing.

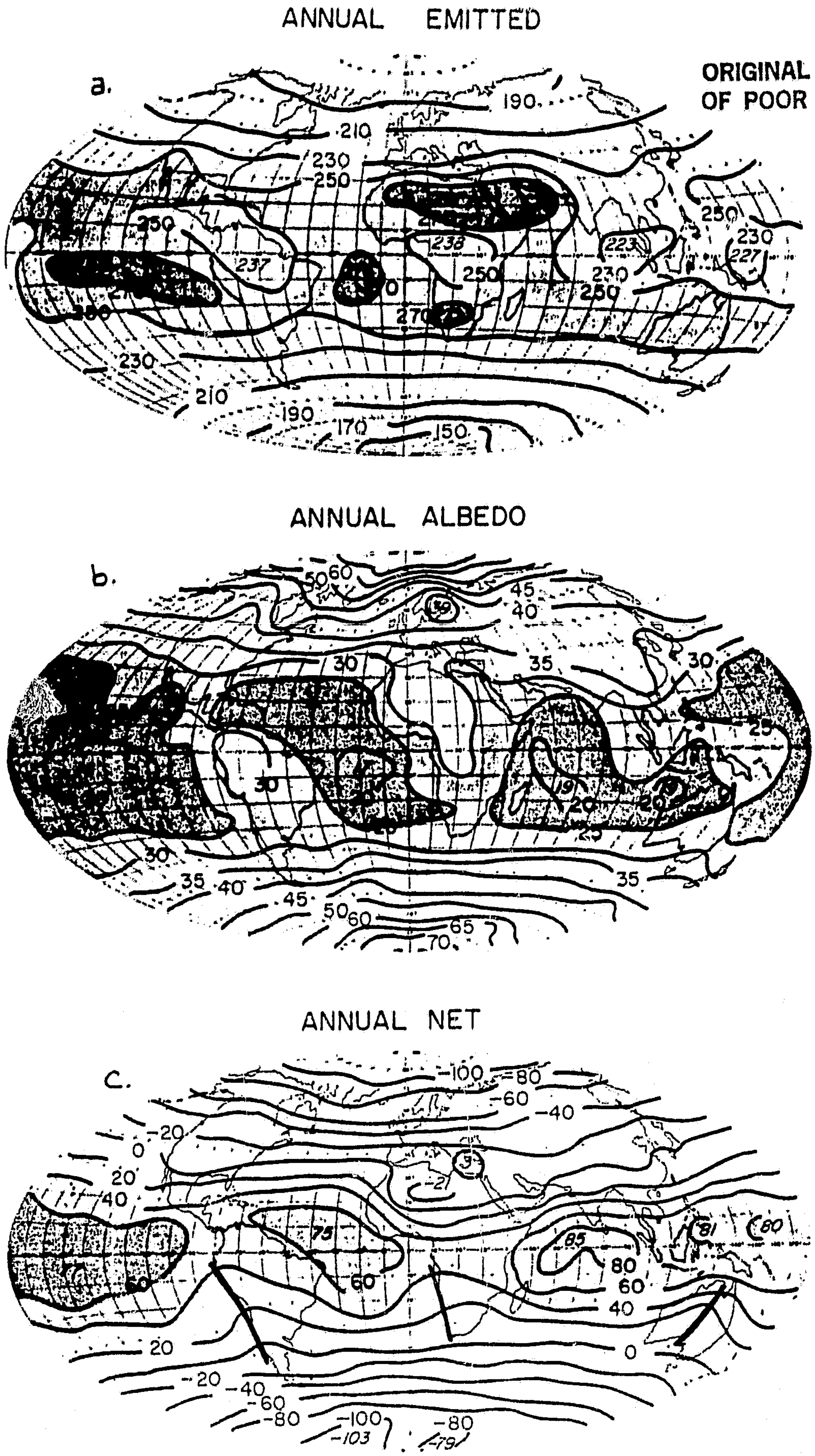
After considerable study of various factors involved, results of this research have led to a description and prioritization of some additional general short-term climate (annual cycles) experiments that have been suggested by the increasing accumulation of satellite radiation budget data. These experiments are discussed below and result from many years of study that has been capped for the purpose of this study with the preliminary results from NIMBUS 6 and NIMBUS 7 satellites. It is very important to recognize that while a wide range of climate model experiments can be done we definitely, in view of limited resources, have to determine which of those many experiments should be done.

This report will also discuss the possibilities for actually doing these experiments. Finally, the last step in the logic chain is to determine which experiments will be done. This depends upon the availability of resources (e.g., computer models, access to computer time, personnel,

salary coverage). It is the intent of this report to discuss the should and can be done sequence based on the results of the last several months' study.

As has been mentioned in preliminary reports, the identification of an apparent three-wave pattern in the net radiation in the mid-latitudes of the southern hemisphere has significant implications for impact on the annual cycle. Three "heat sink" regions are found in our summaries of the satellite measurements to exist over (a) the Australian Desert, (b) the stratocumulus region west of South America, (c) the stratocumulus region west of South Africa. These areas show relative minima in net radiation for their latitude zone which results from the bright, relatively warm cloud and/or surface features located at these positions. The specific longitudinal centers of the regions are 10-20°E, 130°E, 70-80°W as shown in Figure 5 (from Stephens et al., 1981). We definitely believe this to be a high priority climate modeling experiment, namely to impose the three heat sink regions in a major way into the normal circulation pattern in a model simulation. We hypothesize that thesse three heat sink regions will be reflected in the dynamic circulation pattern of the southern hemisphere in a way similar to that which might have arisen from orographic effects. Since the southern hemisphere circulation makes demands upon the energy from the northern hemisphere and also of course feeds certain cross equatorial flow patterns, this southern hemisphere experiment might be extremely important in looking at the interannual variation of climate and weather over the northern hemisphere.

FIGURE 5. From Stephens, Campbell, Vonder Haar, JGR (1981)



Mean annual map of outgoing infrared radiation in W m^{-2}, planetary albedo (%), and net radiation (W m^{-2}) for the 48-month period.

A third climate experiment has been suggested by the data shown in Figure 6. Vonder Haar and Ellis, a number of years ago, and other researchers in the course of our present study, have identified the semiannual component amid the more dominant annual cycle of global planetary albedo. Figure 7 shows the data sets as compiled by Ellis and Vonder Haar (1976) and, in addition, indicates the extremely interesting results from a model run a few years ago by Hansen (personal communication). The ordinate showing absolute albedo percentage values demonstrates that during the course of an annual cycle, the focus of climate study in the U. S. during the next 5-10 years, the northern hemisphere snow-covered continent exerts a pulse upon the entire global albedo pattern in the period March - July. This example is for the "normal" case and we immediately hypothesized that an abnormal wintertime circulation, bringing with it a low amount of snowfall accumulation and/or an abnormal early spring situation (with large amounts of warm air advection from lower latitudes), could give rise to a particular year when the snow cover is not present at the time of increasing insolation over the higher latitudes of the northern hemisphere! This situation would represent a distinct anomaly for the earth, primarily in these latitudes, and the response is yet to be determined. Satellite observations of this situation will, of course, be continued with the ERBE measurements. We believe a climate experiment to begin to study the potential impact on the important springtime and summertime northern hemisphere circulations that might arise from such interannual variability is important to consider at this time. A three-dimensional time-dependent climate model would be required to complete this experiment by imposing and running the situation with and without the satllite-observed effect.

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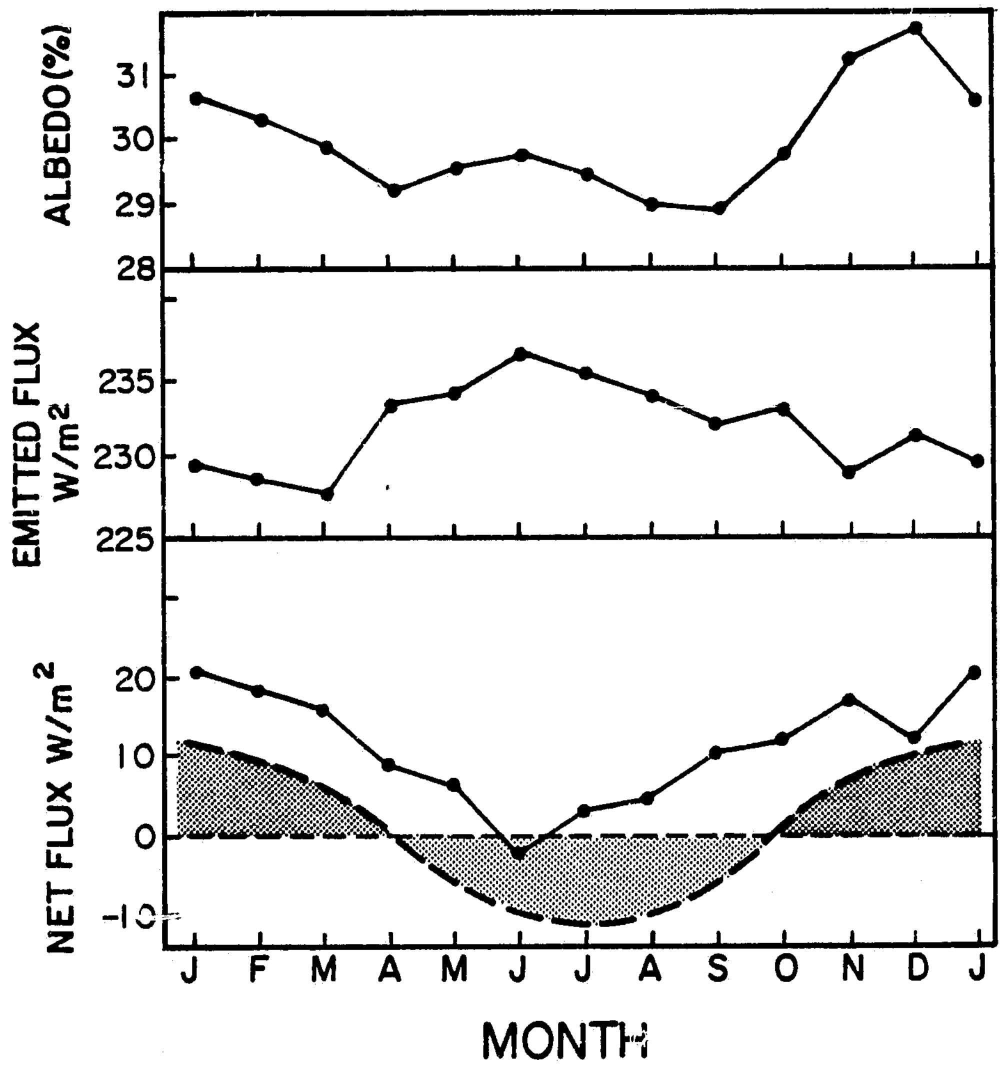
Figure 6

The ANNUAL CYCLE
of Global Radiation Budget



From Satellite Observations (48 months during the 1964–1977 period)

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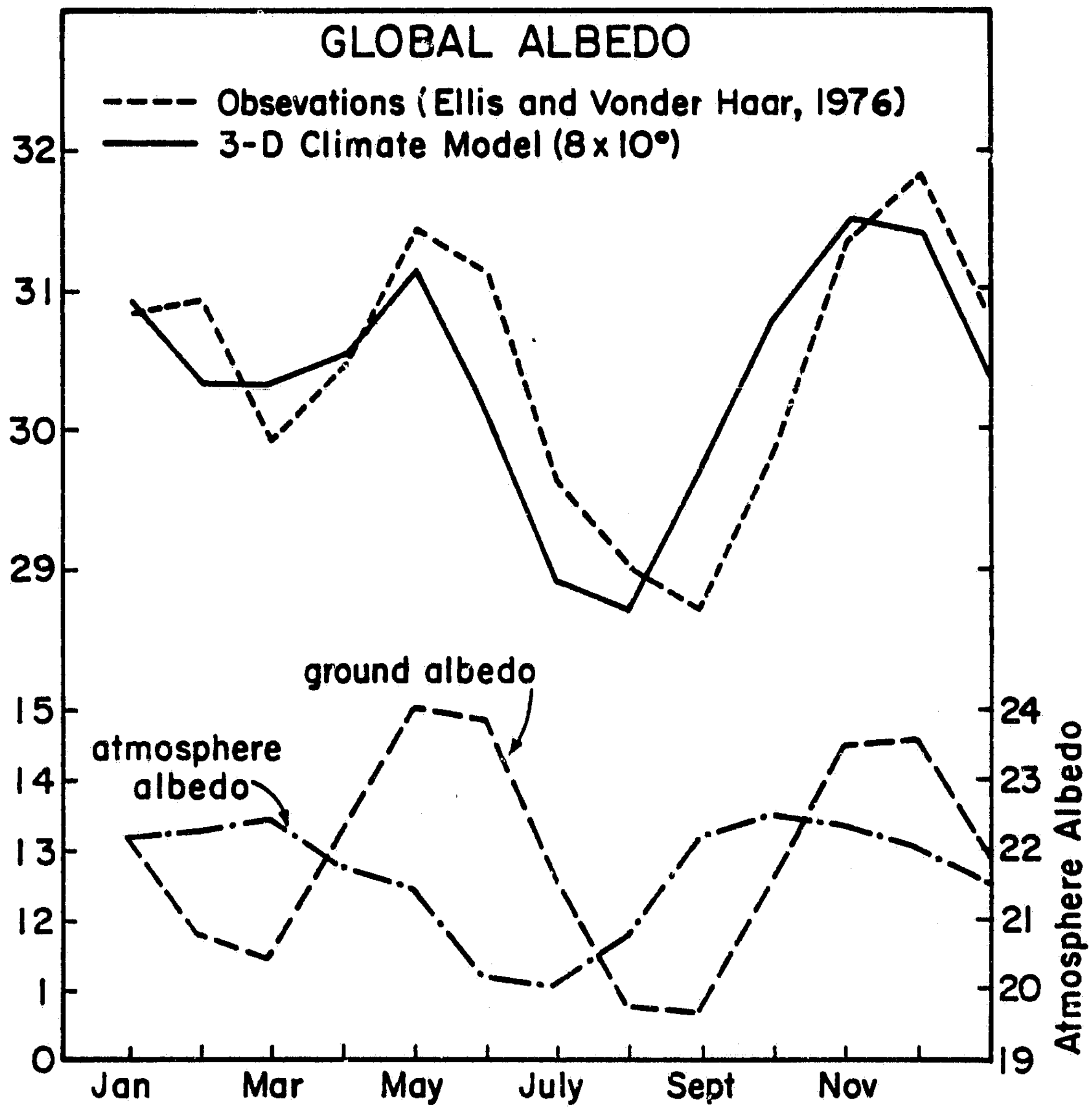
Figure 7



from J. Hansen (1978)

A fourth climate-related experiment suggested by our research has its roots in the very early days of the satellite radiation budget measurements. Data from TIROS IV in 1962, (House, F., personal communcation) showed the Sahara Desert to lose more energy than it had gained during the course of a year. Vonder Haar and Suomi (1971) and Raschke et al., (1973) verified the earlier result with NIMBUS-3 data. This occurrence places an abnormal pulse in the net radiation pattern at that latitude zone of the northern hemisphere (as is also shown in Figure 5). The consequence of this net energy loss at rela tively low latitudes has not yet been fully explained but the work of Charney (1975) and others began to study it. We expect and hypothesize that sinking air warmed adiabatically is responsible for balancing the local region heat budget. The source of this descending air (it must rise from somewhere) is yet to be determined. The activity of this inferred regional circulation pattern may influence the weather and climate in a much broader region than just the Sahara. Of course, the sub-Sahara region, the Sahel, is a region of concern because of its marginal food production capabilities and its indigenous poulation, dependent upon that food. We hypothesize that the net radiation heat sink observed from the satellite is related to the upward circulation in the Indian monsoon area and also related in part to the extreme thermal heat low over the Saudi Arabian Peninsula.

A climate experiment to focus on this region would gain a great deal from the recent MONEX experiment that has provided data from the 1979 monsoon season. Also, the global weather experiment (FGGE), has provided data to examine the dynamic flow patterns near the Sahara much better than had been possible earlier. Indeed, the principal investigator and a student attempted to explore this radiation budget anamoly in the early 1970's and found the data set to be inadequate at that time. Now, however, the climate experiment to focus on this very important region of the northern hemisphere with this possible impact on the food production all across Africa and the Indian sub-continent can be carried out.

A fifth and by no means low priority cliamte experiment, yet one that needs further definition, has to do with the region to the southwest of the U. S. in the eastern central Pacific. Here, we find an extremely large region of stratocumulus clouds that form a delicate radiative-dynamic balance between ocean, atmosphere processes. The region is "upstream" from the U. S. insofar as influencing our weather patterns which in the aggregate give rise to the interannual variation of climate. This stratocumulus region has been observed from the satellite to fluctuate rather largely from one year to another and because of its stratus cloud cover may be exceedingly important for climate (Vonder Haar and Stephens paper regarding radiatively important clouds for climate, in preparation). We recognize it to be a potentially major, yet variable, heat sink region near our shores. A climate experiment to assess the impact of these clouds on the subsequent development of circulation, particularly in the fall and winter periods of the northern hemisphere is another that has been identified by the present research.

Recent results by Kutzbach and Otto-Bliesner (1982) have demonstrated that study of past climate and the variations in radiational forcing which we know have occurred due to orbital geometry can give rise to insights and information pertaining to present and future climate situations. Their work with a low order climate model focused on the monsoon situation, the continent-ocean effect that is driven and amplified by radiational differences. Their work is an example of the type of research we are emphasizing in our current project to fill the bridge between the observations from radiation budget experiments on satellites and the climate model studies that they suggest and support. The experiments that they have carried out using two different models have been very well received in the scientific community and give further impetus to the continuation of the work which has been begun in the present study.

Comparison of the models of Kutzbach and Otto-Bliesner, Hanna (1982; see Appendix 2-2), Blackmon (the NCAR Community Climate Model) and others demonstrates that the ability for moderately sophisticated climate models to simulate annual cycles is no longer limited by computer resources. Insofar as the radiation budget experiments are concerned each model's parameterization (or specification) of cloud/radiation processes and surface radiative processes is an increasingly important factor. Of course, on the shorter time scales of a few seasons or years prevailing widsom indicates that ocean energy intake/output may be specified. For longer time periods the explicit heat transport provided by (often wind-driven) ocean currents must be more deterministic. Finally, the choice of models for certain experiments must rest on information about the model's sen-

sitivity or "signal-to-noise". In the 1980's models, just as instruments, must be properly chosen for the task at hand.

3.0 Conclusions and Suggestions for Future Research

3.1 Conclusions from the Present Study

During this research project we have completed a two-phase approach to the problem of use of radiation budget measurements in climate modeling. First, we have updated and summarized the existing record of satellite radiation budget experiments. Secondly, from this new archive we have chosen and discussed specific climate experiments which should be carried out as part of continuing research in accord with the U. S. Climate Program.

In addition, we have reviewed the results of experiments with several new low order spectral climate models, one developed locally. The initial results from these models demonstrate that the radiation budget-related climate experiments noted above can be done.

Finally, we propose to actually carryout some of the model experiments under further research supported by and in collaboration with NASA. What will be done in this research area depends upon future funding.

3.2 Future Research

With the NIMBUS-7 radiation budget data sets now joining those from NIMBUS-6, it is timely to close even further the gap between our more definitive data sets and the improving climate models. Tests and experiments completed in the next few years can be followed by the new, improved Earth Radiation Budget Experiment (ERBE) data. This opportunity to confirm, deny or add to the data base in view of model experiments provides a clear scientific path. Under a separate proposal to NASA we will seek to

pursue such research along with other groups. The probabilities for success are very high and the results will contribute to progress in the U.S. Climate Program.

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APPENDIX 1

ARCHIVE OF EARTH RADIATION

BUDGET DATA SETS AT CSU

by

P. E. Ciesielski and T. H. Vonder Haar

Department of Atmospheric Science
Colorado State University
Fort Collins, CO 80523

Special Report

NASA Contract NAG-1-150

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1.0 INTRODUCTION

Our purpose in assembling and documenting an archive of earth radiation budget (ERB) data is to make an extensive data base from earth orbiting satellites available for research purposes. The data sets discussed in this document are contained on a single magnetic tape in a format that can easily be read on most computer systems. In addition to the documentation for reading this tape, we have included pertinent information about the ERB measurements with appropriate references for those desiring additional detailed information.

2.0 SATELLITE DATA SOURCES

Table 1 summarizes the temporal distribution of the ERB data sets for this archive. Listed in this table are 123 data sets which were assembled from the 17-year period extending from 1962 to 1978. One hundred eighteen of these data sets represent monthly or semi-monthly averaged measurements, while the other five comprising data from TIROS 5 and TIROS 7 represent seasonally averaged measurements.

Each data set is composed of the following radiation budget components: emitted radiant exitance (i.e., longwave flux), reflected flux, incident flux, albedo and net radiation balance. Of these five components, the emitted radiant exitance and the albedo at the top of the atmosphere are the fundamental analyzed measurements of all ERB experiments. From these two components one can derive the net gain of energy of the earth-atmosphere system as shown in Equation 1.

$$\begin{aligned}\text{NET} &= \text{INCIDENT} - \text{REFLECTED} - \text{EMITTED} \\ &= \text{INCIDENT}\ (1 - \text{ALBEDO}) - \text{EMITED} \qquad (1)\end{aligned}$$

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Table 1. Chronological list of earth orbiting satellites for which data is available at CSU.

Month	1962	1963	1964	1965	1966	1968	1969	1970	1971	1974	1975	1976	1977	1978
Jan			T7{DJF}	[EX](1030)			[E7]	[N3]			NSR	NSR[N6]	NSR[N6]	NSR[N6]
Feb				[EX](1035)			[E7]				NSR	NSR[N6]	NSR[N6]	NSR[N6]
Mar				[EX](1040)			[E7]		NO1		NSR	NSR[N6]	NSR[N6]	[N6]
Apr	T4{MAM}		T7{MAM}	EX(0840)			E7[N3]*	I1	NO1		NSR	NSR[N6]	NSR[N6]	[N6]
May				EX(0855)			[N3]	I1			NSR	NSR[N6]	NSR[N6]	[N6]
Jun				EX(0910)			[N3]	I1		NSR	NSR	NSR[N6]	NSR[N6]	
Jul		T7{JJA}	[EX](0830)	EX(0925)	[N2]*		[N3]			NSR	NSR[N6]*	NSR[N6]	NSR[N6]	
Aug			[EX](0855)	EX(0940)			[N3]			NSR	NSR[N6]	NSR[N6]	NSR[N6]	
Sep			[EX](0915)	EX(1000)						NSR	NSR[N6]	NSR[N6]	NSR[N6]	
Oct		T7{SON}	[EX](0940)	EX(1020)		[E7]	[N3]			NSR	NSR[N6]	NSR[N6]	NSR[N6]	
Nov			[EX](1005)	EX(1040)		[E7]				NSR	NSR[N6]	NSR[N6]	NSR[N6]	
Dec			[EX](1030)		[E3]	[E7]				NSR	NSR[N6]	NSR[N6]	NSR[N6]	

T4 -- TIROS 4

T7 -- TIROS 7

EX -- Experimental Satellites

N2 -- Nimbus 2

E3 -- ESSA 3

NO1 -- NOAA 1

E7 -- ESSA 7

N3 -- Nimbus 3

NSR -- NOAA Scanning Radiometer (4-satellites)

I1 -- ITOS 1

N6 -- Nimbus 6

{months contained in seasonal average} -- seasonal average

( ) -- Approximate local time at which experimental satellites crossed equator during daylight hours;

[ ] -- Data sets which we feel provide the best estimate of the earth's radiation budget.

* -- Albedo corrected for diurnal variation of reflection with directional reflectance model.

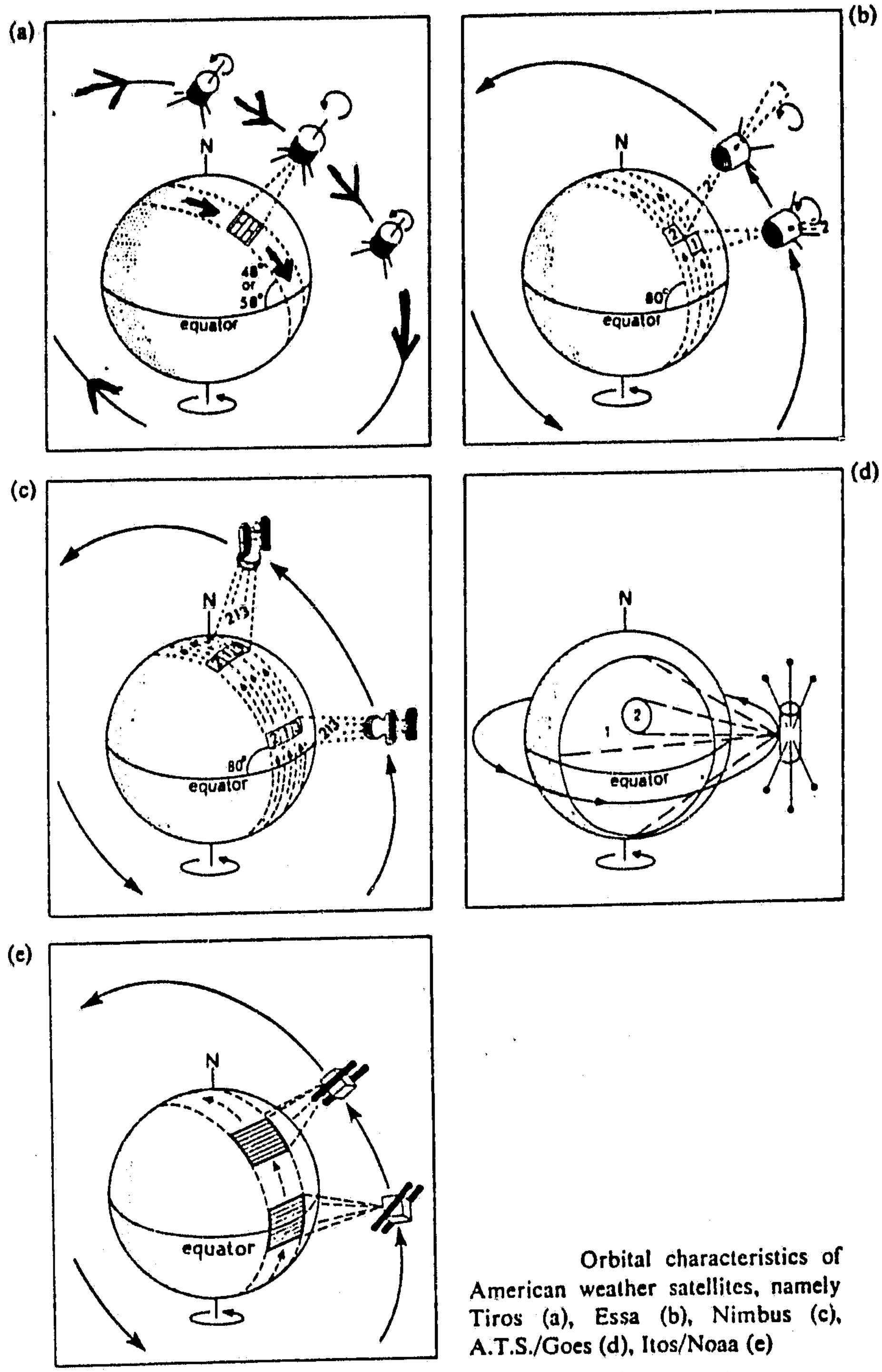
For consistency in calculating the average incident flux for each month, we have used the NIMBUS-7 observation of 1376 watts per square meter (Hickey et al., 1980).

As shown in Table 1, eleven different experiments contribution to the archive presented here. The orbital characteristics of these satellite systems are illustrated in Figure 1 and listed in Table 2. Since the radiation budget measurements from these satellites are of variable accuracy and resolution, we have indicated in Table 1 which data sets we feel provide the best estimates of the earth's radiation budget. In general, the absolute accuracy of an individual month of data is ± 5% (Ellis and Vonder Haar, 1976). The relative accuracy is better though, probably being ±3% for emitted and ±4% for albedo. For more information concerning error estimates and resolution of the data, one should refer to Campbell and Vonder Haar (1980a).

The data sets in this archive are comprised of measurements from two fundamentally different types of sensors: scanning radiometers and wide angle or flat plate disc sensors. The difference in these two sensors in evident in Figure 2.

The scanning radiometer (SR) is a higher resolution instrument measuring the radiant energy confined to a particular direction and to a small but finite solid angle (Figure 1b). These scanning instruments were employed on board NIMBUS-2 and NIMBUS-3 (Raschke and Bandeen, 1970 and Raschke, et al., 1973) as well as on NIMBUS-6 and the NOAA SR satellites (Winston et al., 1979).

Emitted radiances from these scanners are analyzed with limb darkening models, while upwelling solar radiation is converted to top of the



Orbital characteristics of American weather satellites, namely Tiros (a), Essa (b), Nimbus (c), A.T.S./Goes (d), Itos/Noaa (e)

FIGURE 1. Modified from Barrett (1974)

TABLE II

SATELLITE	ANGLE OF ORBIT TO EQUATOR (°)	LOCAL TIME OF EQUATORIAL CROSSING DURING DAYLIGHT HOURS
TIROS 4	48	VARIABLE
TIROS 7	58	VARIABLE
EXPERIMENTAL	60	VARIABLE (see Table 1)
NIMBUS 2	100	11:30
NIMBUS 3	100	13:40
ESSA 3	101	14:30
ESSA 7	102	11:30
ITOS 1	102	15:00
NOAA 1	102	15:00
Nimbus 6	100	11:45
NOAA SR	102	9:00
Nimbus 7	104	12:00

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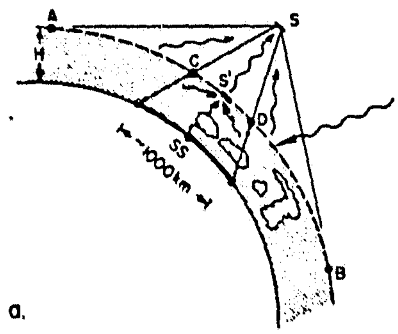

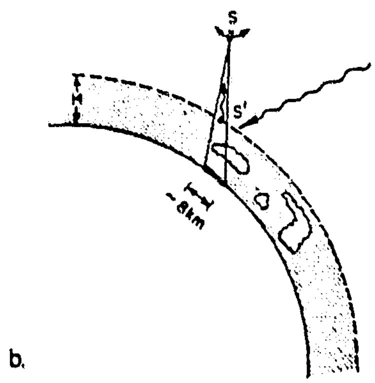

Schematic representation of the measured quantities by (*a*) a flat plate and (*b*) scanning detector.

Figure 2. From Stephens, et al. (1981)

atmosphere albedo using complicated bi-directional and directional reflectance models. The major disadvantage to using the NOAA SR data sets is that these satellites measured the upwelling radiation in narrow spectral region (0.5 - 0.7 μ in the visible and 10.5 - 12.5 μ in the infrared). Thus, the total energy exchange between earth and atmosphere was not measured.

All remaining satellite measurements were made with flat plate disc sensors. Measurements from these sensors have two major advantages over the scanner: (1) measurements are broadband (i.e., they measure the upwelling solar radiation in the spectral region from 0.2 to 3.8μ and the infrared emitted flux in the 3.8 to >50μ spectral range), and (2) measurements represent radiant energy integrated over a broad variation of angles. The full field of view of the flat plate sensor is ~ 60°, but the effective resolution is on the order of 10° for satellites with orbits of height ~ 600 km (Stephens et al., 1981). This feature of flat plate sensors results from the fact that the radiation from the subsatellite point is more heavily weighted than radiation from the limb. In contrast, scanning radiometers have a far better spatial resolution varying from 50 km of great circle arc distance to nadir to 110 km at an angle of 40° from nadir (Raschke and Bandeen, 1970).

In order to give the data sets discussed here scientific utility, all users are strongly encouraged to refer to the references listed in Table 3 for further background information concerning the various satellite experiments.

TABLE III

SATELLITE	REFERENCE
TIROS 4, TIROS 7	Bandeen, *et. al.*, 1965
EXPERIMENTAL	Vonder Haar, 1968
ESSA 3, ESSA 7	MacDonald, 1970
Nimbus 2, Nimbus 3	Raschke and Bandeen, 1970, Raschke, *et. al.*, 1973
ITOS, NOAA 1	Flanders and Smith, 1975
NOAA SR	Winston, *et. al.*, 1979
Nimbus 6	Campbell and Vonder Haar, 1980b

3.0 SPATIAL AND TEMPORAL SAMPLING BIASES

One major deficiency of the satellites discussed in this archive lies in the fact that their sun-synchronous orbits result in serious spatial and temporal sampling biases.

As one can note from Figure 1, satellites with sun-synchronous orbits do not pass directly over the polar regions. As a result the earth's radiation viewed from those regions by flat plate sensors is at some oblique angle. If the inclination angle of the satellite's orbit is extremely low as in the TIROS and EXPERIMENTAL series, then measurements simply do not exist over the polar regions. In the case of the TIROS satellites no measurements exist poleward of 62.5^o latitude. For satellites which orbit at higher inclination angles, the determination of planetary albedo poleward of about 70^o latitude from flat plate sensors is subject to some uncertainty. This results from the large angular corrections which must be applied to these measurements, the validity of which is still questionable. Other spatial sampling biases are included in the January 21 to February 3, 1970 period (shown in Table 1 as January, 1970) in which NIMBUS-3 data were missing from eastern Asia to south of Australia. Furthermore, NIMBUS-3 night-time infrared exitance samples are missing over a large area of western Europe, western Africa and the South Atlantic (Raschke, et al., 1973).

The major temporal sampling biases result from the local time sampling inherent in sun-synchronous satellites. (See Table 2 for the approximate local time at which the satellite crossed the equator on the daylight part of the orbit). These satellites sample at the same local time (or nearly so) each day, so that their measurements are representative at that time

but do not account for diurnal variations in the state of the atmosphere (such as cloudiness and radiating temperatures). Some attempts, as noted in Table 1, have been made to correct for possible diurnal biases in reflectance due to varying solar elevation. The seasonally averaged data sets from the TIROS series do not contain this diurnal bias since their orbital procession allowed sampling at all local times over a period of less than three months (76 days for TIROS-7). Finally, because of problems with the recorders onboard NIMBUS-6, only daytime emitted measurements are available from this satellite.

4.0 FORMAT OF TAPE

As mentioned earlier in this document, the data sets in Table 1 are contained on a single magnetic tape. This tape has the following characteristics: 1600 bits per inch, 9 track, unlabeled and written in long-block stranger format. The data were written to tape using a CDC 60-bit machine.

5.0 FORMAT OF DATA

Table 1 lists the 123 data sets that are contained on the magnetic tape mentioned above. Each data set contains five records of information corresponding to the five following fields: emitted flux, reflected flux, incident flux, albedo and net radiation flux. In total, there are 615 records on the tape. The constituents of each record are a field of data

in the form of a 36 by 18 array preceded by six integer labels which identify the field. Appendix A lists the identifier labels for all the records on the tape along with the code for interpreting these labels. For example, the labels for the first record on the tape are: RN = 1, LOA = 1, SS = 3, MN = 7, YEAR = 1964 and TOF = 1. These labels signify that this field of data is on the first record of the tape, the data were averaged on a monthly basis, the field was obtained from the EXPERIMENTAL satellites for the month of July, 1964, and finally, the type of field is emitted flux.

Each record was written to tape using a "buffer out" statement with an add parity, which allowed the data to be written in a binary mode. To make reading the tape universal to all systems, each data value in the (36,18) arrays was converted to a positive integer. To convert the integer data arrays (I) read in from the tape back to the actual data values (ADV), each user must employ the conversion shown in Equation 2.

$$ADV = (FLOAT\ (I)\ /\ 1000.) - 1000. \qquad (2)$$

A sample program and printout for reading and converting values from the tape back to their actual values is shown in Appendix B for the first record on the tape.

Each (36,18) array on the tape represents a global grid of data with 10^{o} resolution in both latitudinal and longitudinal directions. The first index of this array is a longitudinal indicator which increases towards the east, while the second index, being a latitudinal indicator, increases in a southerly direction. Therefore, as shown in Figure 3, point (1,1) is associated with 5^{o}E, 85^{o}N, while point (36,18) corresponds to 355^{o}E, 85^{o}S.

Each data value represents an average over a $10^{\circ} \times 10^{\circ}$ area centered at that point. Missing data were assigned the value - 999.999.

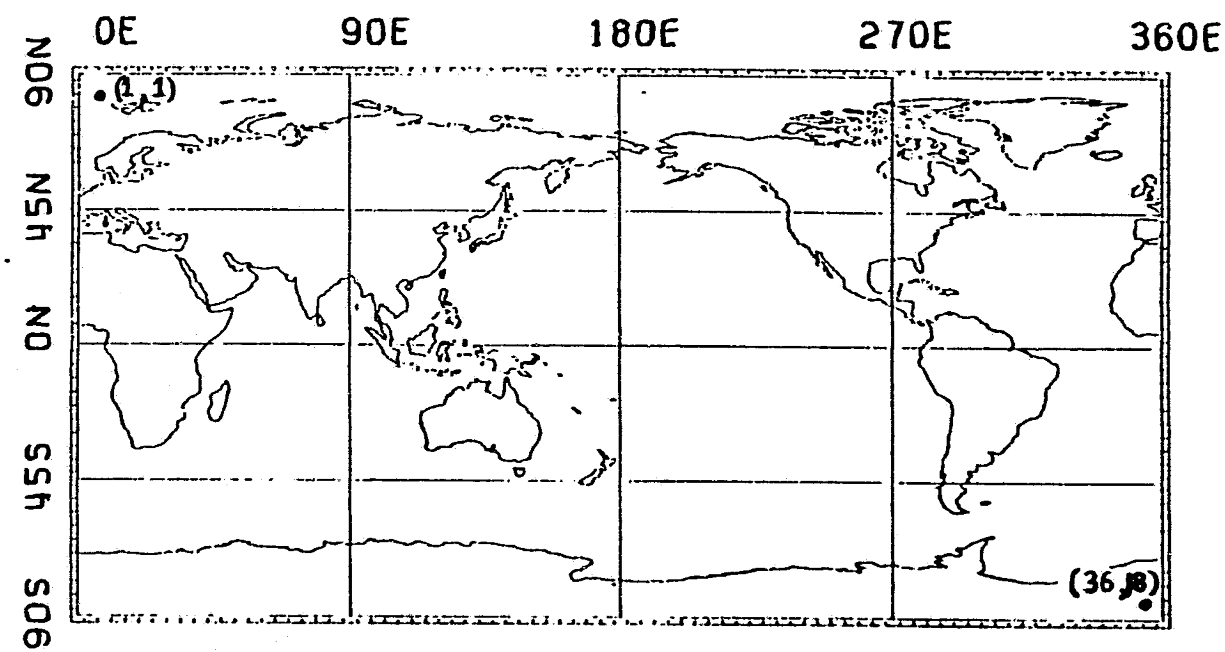

Figure 3. Grid coverage corresponding to data fields on tape. Location of points (1,1) and (36,18) indicated with a period.

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APPENDIX A

RN	-	Record Number on Tape
LOA	-	Length of Average (1-Monthly, 2-Seasonal)
SS	-	Satellite System (1-TIROS 4, 2-TIROS 7, 3-Experimental, 4-NIMBUS 2, 5-ESSA 3, 6-ESSA 7, 7-NIMBUS 3, 8-TIROS 1, 9-NOAA 1, 10-NOAA SR, 11-NIMBUS 6, 12-NIMBUS 7)
MN	-	Month or Season Data were Taken (1-January, 2-February, 3-March, 4-April, 5-May, 6-June, 7-July, 8-August, 9-September, 10-October, 11-November, 12-December, 13-Winter [Dec, Jan, Feb], 14-Spring [Mar, Apr, May], 15-Summer [June, July, Aug], 16-Fall [Sept, Oct, Nov])
YEAR	-	Year Data were Taken
TOF	-	Type of Field (1-Emitted, 2-Reflected, 3-Incident, 4-Albedo, 5-Net)

RN - Record Number on Tape
LOA - Length of Average
SS - Satellite System
MN - Month or Season Data were Taken
YEAR - Year Data were Taken
TOF - Type of Field

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RN	LOA	SS	MN	YEAR	TOF	RN	LOA	SS	MN	YEAR	TOF
1	1	3	7	1964	1	69	1	3	8	1965	4
2	1	3	7	1964	2	70	1	3	8	1965	5
3	1	3	7	1964	3	71	1	3	9	1965	1
4	1	3	7	1964	4	72	1	3	9	1965	2
5	1	3	7	1964	5	73	1	3	9	1965	3
6	1	3	8	1964	1	74	1	3	9	1965	4
7	1	3	8	1964	2	75	1	3	9	1965	5
8	1	3	8	1964	3	76	1	3	10	1965	1
9	1	3	8	1964	4	77	1	3	10	1965	2
10	1	3	8	1964	5	78	1	3	10	1965	3
11	1	3	9	1964	1	79	1	3	10	1965	4
12	1	3	9	1964	2	80	1	3	10	1965	5
13	1	3	9	1964	3	81	1	3	11	1965	1
14	1	3	9	1964	4	82	1	3	11	1965	2
15	1	3	9	1964	5	83	1	3	11	1965	3
16	1	3	10	1964	1	84	1	3	11	1965	4
17	1	3	10	1964	2	85	1	3	11	1965	5
18	1	3	10	1964	3	86	1	4	7	1966	1
19	1	3	10	1964	4	87	1	4	7	1966	2
20	1	3	10	1964	5	88	1	4	7	1966	3
21	1	3	11	1964	1	89	1	4	7	1966	4
22	1	3	11	1964	2	90	1	4	7	1966	5
23	1	3	11	1964	3	91	1	5	12	1966	1
24	1	3	11	1964	4	92	1	5	12	1966	2
25	1	3	11	1964	5	93	1	5	12	1966	3
26	1	3	12	1964	1	94	1	5	12	1966	4
27	1	3	12	1964	2	95	1	5	12	1966	5
28	1	3	12	1964	3	96	2	1	14	1962	1
29	1	3	12	1964	4	97	2	1	14	1962	2
30	1	3	12	1964	5	98	2	1	14	1962	3
31	1	3	1	1965	1	99	2	1	14	1962	4
32	1	3	1	1965	2	100	2	1	14	1962	5
33	1	3	1	1965	3	101	2	2	15	1963	1
34	1	3	1	1965	4	102	2	2	15	1963	2
35	1	3	1	1965	5	103	2	2	15	1963	3
36	1	3	2	1965	1	104	2	2	15	1963	4
37	1	3	2	1965	2	105	2	2	15	1963	5
38	1	3	2	1965	3	106	2	2	16	1963	1
39	1	3	2	1965	4	107	2	2	16	1963	2
40	1	3	2	1965	5	108	2	2	16	1963	3
41	1	3	3	1965	1	109	2	2	16	1963	4
42	1	3	3	1965	2	110	2	2	16	1963	5
43	1	3	3	1965	3	111	2	2	13	1964	1
44	1	3	3	1965	4	112	2	2	13	1964	2
45	1	3	3	1965	5	113	2	2	13	1964	3
46	1	3	4	1965	1	114	2	2	13	1964	4
47	1	3	4	1965	2	115	2	2	13	1964	5
48	1	3	4	1965	3	116	2	2	14	1964	1
49	1	3	4	1965	4	117	2	2	14	1964	2
50	1	3	4	1965	5	118	2	2	14	1964	3
51	1	3	5	1965	1	119	2	2	14	1964	4
52	1	3	5	1965	2	120	2	2	14	1964	5
53	1	3	5	1965	3	121	1	10	6	1974	1
54	1	3	5	1965	4	122	1	10	6	1974	2
55	1	3	5	1965	5	123	1	10	6	1974	3
56	1	3	6	1965	1	124	1	10	6	1974	4
57	1	3	6	1965	2	125	1	10	6	1974	5
58	1	3	6	1965	3	126	1	10	7	1974	1
59	1	3	6	1965	4	127	1	10	7	1974	2
60	1	3	6	1965	5	128	1	10	7	1974	3
61	1	3	7	1965	1	129	1	10	7	1974	4
62	1	3	7	1965	2	130	1	10	7	1974	5
63	1	3	7	1965	3	131	1	10	8	1974	1
64	1	3	7	1965	4	132	1	10	8	1974	2
65	1	3	7	1965	5	133	1	10	8	1974	3
66	1	3	8	1965	1	134	1	10	8	1974	4
67	1	3	8	1965	2	135	1	10	8	1974	5
68	1	3	8	1965	3	136	1	10	9	1974	1

RN	LOA	SS	MN	YEAR	TOF	RN	LOA	SS	MN	YEAR	TOF
137	1	10	9	1974	2	217	1	10	1	1976	2
138	1	10	9	1974	3	218	1	10	1	1976	3
139	1	10	9	1974	4	219	1	10	1	1976	4
140	1	10	9	1974	5	220	1	10	1	1976	5
141	1	10	10	1974	1	221	1	10	2	1976	1
142	1	10	10	1974	2	222	1	10	2	1976	2
143	1	10	10	1974	3	223	1	10	2	1976	3
144	1	10	10	1974	4	224	1	10	2	1976	4
145	1	10	10	1974	5	225	1	10	2	1976	5
146	1	10	11	1974	1	226	1	10	3	1976	1
147	1	10	11	1974	2	227	1	10	3	1976	2
148	1	10	11	1974	3	228	1	10	3	1976	3
149	1	10	11	1974	4	229	1	10	3	1976	4
150	1	10	11	1974	5	230	1	10	3	1976	5
151	1	10	12	1974	1	231	1	10	4	1976	1
152	1	10	12	1974	2	232	1	10	4	1976	2
153	1	10	12	1974	3	233	1	10	4	1976	3
154	1	10	12	1974	4	234	1	10	4	1976	4
155	1	10	12	1974	5	235	1	10	4	1976	5
156	1	10	1	1975	1	236	1	10	5	1976	1
157	1	10	1	1975	2	237	1	10	5	1976	2
158	1	10	1	1975	3	238	1	10	5	1976	3
159	1	10	1	1975	4	239	1	10	5	1976	4
160	1	10	1	1975	5	240	1	10	5	1976	5
161	1	10	2	1975	1	241	1	10	6	1976	1
162	1	10	2	1975	2	242	1	10	6	1976	2
163	1	10	2	1975	3	243	1	10	6	1976	3
164	1	10	2	1975	4	244	1	10	6	1976	4
165	1	10	2	1975	5	245	1	10	6	1976	5
166	1	10	3	1975	1	246	1	10	7	1976	1
167	1	10	3	1975	2	247	1	10	7	1976	2
168	1	10	3	1975	3	248	1	10	7	1976	3
169	1	10	3	1975	4	249	1	10	7	1976	4
170	1	10	3	1975	5	250	1	10	7	1976	5
171	1	10	4	1975	1	251	1	10	8	1976	1
172	1	10	4	1975	2	252	1	10	8	1976	2
173	1	10	4	1975	3	253	1	10	8	1976	3
174	1	10	4	1975	4	254	1	10	8	1976	4
175	1	10	4	1975	5	255	1	10	8	1976	5
176	1	10	5	1975	1	256	1	10	9	1976	1
177	1	10	5	1975	2	257	1	10	9	1976	2
178	1	10	5	1975	3	258	1	10	9	1976	3
179	1	10	5	1975	4	259	1	10	9	1976	4
180	1	10	5	1975	5	260	1	10	9	1976	5
181	1	10	6	1975	1	261	1	10	10	1976	1
182	1	10	6	1975	2	262	1	10	10	1976	2
183	1	10	6	1975	3	263	1	10	10	1976	3
184	1	10	6	1975	4	264	1	10	10	1976	4
185	1	10	6	1975	5	265	1	10	10	1976	5
186	1	10	7	1975	1	266	1	10	11	1976	1
187	1	10	7	1975	2	267	1	10	11	1976	2
188	1	10	7	1975	3	268	1	10	11	1976	3
189	1	10	7	1975	4	269	1	10	11	1976	4
190	1	10	7	1975	5	270	1	10	11	1976	5
191	1	10	8	1975	1	271	1	10	12	1976	1
192	1	10	8	1975	2	272	1	10	12	1976	2
193	1	10	8	1975	3	273	1	10	12	1976	3
194	1	10	8	1975	4	274	1	10	12	1976	4
195	1	10	8	1975	5	275	1	10	12	1976	5
196	1	10	9	1975	1	276	1	10	1	1977	1
197	1	10	9	1975	2	277	1	10	1	1977	2
198	1	10	9	1975	3	278	1	10	1	1977	3
199	1	10	9	1975	4	279	1	10	1	1977	4
200	1	10	9	1975	5	280	1	10	1	1977	5
201	1	10	10	1975	1	281	1	10	2	1977	1
202	1	10	10	1975	2	282	1	10	2	1977	2
203	1	10	10	1975	3	283	1	10	2	1977	3
204	1	10	10	1975	4	284	1	10	2	1977	4
205	1	10	10	1975	5	285	1	10	2	1977	5
206	1	10	11	1975	1	286	1	10	3	1977	1
207	1	10	11	1975	2	287	1	10	3	1977	2
208	1	10	11	1975	3	288	1	10	3	1977	3
209	1	10	11	1975	4	289	1	10	3	1977	4
210	1	10	11	1975	5	290	1	10	3	1977	5
211	1	10	12	1975	1	291	1	10	4	1977	1
212	1	10	12	1975	2	292	1	10	4	1977	2
213	1	10	12	1975	3	293	1	10	4	1977	3
214	1	10	12	1975	4	294	1	10	4	1977	4
215	1	10	12	1975	5	295	1	10	4	1977	5
216	1	10	1	1976	1	296	1	10	5	1977	1

RN	LOA	SS	MN	YEAR	TOF	RN	LOA	SS	MN	YEAR	TOF
297	1	10	5	1977	2	377	1	11	1	1976	2
298	1	10	5	1977	3	378	1	11	1	1976	3
299	1	10	5	1977	4	379	1	11	1	1976	4
300	1	10	5	1977	5	380	1	11	1	1976	5
301	1	10	6	1977	1	381	1	11	2	1976	1
302	1	10	6	1977	2	382	1	11	2	1976	2
303	1	10	6	1977	3	383	1	11	2	1976	3
304	1	10	6	1977	4	384	1	11	2	1976	4
305	1	10	6	1977	5	385	1	11	2	1976	5
306	1	10	7	1977	1	386	1	11	3	1976	1
307	1	10	7	1977	2	387	1	11	3	1976	2
308	1	10	7	1977	3	388	1	11	3	1976	3
309	1	10	7	1977	4	389	1	11	3	1976	4
310	1	10	7	1977	5	390	1	11	3	1976	5
311	1	10	8	1977	1	391	1	11	4	1976	1
312	1	10	8	1977	2	392	1	11	4	1976	2
313	1	10	8	1977	3	393	1	11	4	1976	3
314	1	10	8	1977	4	394	1	11	4	1976	4
315	1	10	8	1977	5	395	1	11	4	1976	5
316	1	10	9	1977	1	396	1	11	5	1976	1
317	1	10	9	1977	2	397	1	11	5	1976	2
318	1	10	9	1977	3	398	1	11	5	1976	3
319	1	10	9	1977	4	399	1	11	5	1976	4
320	1	10	9	1977	5	400	1	11	5	1976	5
321	1	10	10	1977	1	401	1	11	6	1976	1
322	1	10	10	1977	2	402	1	11	6	1976	2
323	1	10	10	1977	3	403	1	11	6	1976	3
324	1	10	10	1977	4	404	1	11	6	1976	4
325	1	10	10	1977	5	405	1	11	6	1976	5
326	1	10	11	1977	1	406	1	11	7	1976	1
327	1	10	11	1977	2	407	1	11	7	1976	2
328	1	10	11	1977	3	408	1	11	7	1976	3
329	1	10	11	1977	4	409	1	11	7	1976	4
330	1	10	11	1977	5	410	1	11	7	1976	5
331	1	10	12	1977	1	411	1	11	8	1976	1
332	1	10	12	1977	2	412	1	11	8	1976	2
333	1	10	12	1977	3	413	1	11	8	1976	3
334	1	10	12	1977	4	414	1	11	8	1976	4
335	1	10	12	1977	5	415	1	11	8	1976	5
336	1	10	1	1978	1	416	1	11	9	1976	1
337	1	10	1	1978	2	417	1	11	9	1976	2
338	1	10	1	1978	3	418	1	11	9	1976	3
339	1	10	1	1978	4	419	1	11	9	1976	4
340	1	10	1	1978	5	420	1	11	9	1976	5
341	1	10	2	1978	1	421	1	11	10	1976	1
342	1	10	2	1978	2	422	1	11	10	1976	2
343	1	10	2	1978	3	423	1	11	10	1976	3
344	1	10	2	1978	4	424	1	11	10	1976	4
345	1	10	2	1978	5	425	1	11	10	1976	5
346	1	11	7	1975	1	426	1	11	11	1976	1
347	1	11	7	1975	2	427	1	11	11	1976	2
348	1	11	7	1975	3	428	1	11	11	1976	3
349	1	11	7	1975	4	429	1	11	11	1976	4
350	1	11	7	1975	5	430	1	11	11	1976	5
351	1	11	8	1975	1	431	1	11	12	1976	1
352	1	11	8	1975	2	432	1	11	12	1976	2
353	1	11	8	1975	3	433	1	11	12	1976	3
354	1	11	8	1975	4	434	1	11	12	1976	4
355	1	11	8	1975	5	435	1	11	12	1976	5
356	1	11	9	1975	1	436	1	11	1	1977	1
357	1	11	9	1975	2	437	1	11	1	1977	2
358	1	11	9	1975	3	438	1	11	1	1977	3
359	1	11	9	1975	4	439	1	11	1	1977	4
360	1	11	9	1975	5	440	1	11	1	1977	5
361	1	11	10	1975	1	441	1	11	2	1977	1
362	1	11	10	1975	2	442	1	11	2	1977	2
363	1	11	10	1975	3	443	1	11	2	1977	3
364	1	11	10	1975	4	444	1	11	2	1977	4
365	1	11	10	1975	5	445	1	11	2	1977	5
366	1	11	11	1975	1	446	1	11	3	1977	1
367	1	11	11	1975	2	447	1	11	3	1977	2
368	1	11	11	1975	3	448	1	11	3	1977	3
369	1	11	11	1975	4	449	1	11	3	1977	4
370	1	11	11	1975	5	450	1	11	3	1977	5
371	1	11	12	1975	1	451	1	11	4	1977	1
372	1	11	12	1975	2	452	1	11	4	1977	2
373	1	11	12	1975	3	453	1	11	4	1977	3
374	1	11	12	1975	4	454	1	11	4	1977	4
375	1	11	12	1975	5	455	1	11	4	1977	5
376	1	11	1	1976	1	456	1	11	5	1977	1

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RN	LOA	SS	MN	YEAR	TOF
457	1	11	5	1977	2
458	1	11	5	1977	3
459	1	11	5	1977	4
460	1	11	5	1977	5
461	1	11	6	1977	1
462	1	11	6	1977	2
463	1	11	6	1977	3
464	1	11	6	1977	4
465	1	11	6	1977	5
466	1	6	10	1968	1
467	1	6	10	1968	2
468	1	6	10	1968	3
469	1	6	10	1968	4
470	1	6	10	1968	5
471	1	6	11	1968	1
472	1	6	11	1968	2
473	1	6	11	1968	3
474	1	6	11	1968	4
475	1	6	11	1968	5
476	1	6	12	1968	1
477	1	6	12	1968	2
478	1	6	12	1968	3
479	1	6	12	1968	4
480	1	6	12	1968	5
481	1	6	1	1969	1
482	1	6	1	1969	2
483	1	6	1	1969	3
484	1	6	1	1969	4
485	1	6	1	1969	5
486	1	6	2	1969	1
487	1	6	2	1969	2
488	1	6	2	1969	3
489	1	6	2	1969	4
490	1	6	2	1969	5
491	1	6	3	1969	1
492	1	6	3	1969	2
493	1	6	3	1969	3
494	1	6	3	1969	4
495	1	6	3	1969	5
496	1	6	4	1969	1
497	1	6	4	1969	2
498	1	6	4	1969	3
499	1	6	4	1969	4
500	1	6	4	1969	5
501	1	7	4	1969	1
502	1	7	4	1969	2
503	1	7	4	1969	3
504	1	7	4	1969	4
505	1	7	4	1969	5
506	1	7	5	1969	1
507	1	7	5	1969	2
508	1	7	5	1969	3
509	1	7	5	1969	4
510	1	7	5	1969	5
511	1	7	6	1969	1
512	1	7	6	1969	2
513	1	7	6	1969	3
514	1	7	6	1969	4
515	1	7	6	1969	5
516	1	7	7	1969	1
517	1	7	7	1969	2
518	1	7	7	1969	3
519	1	7	7	1969	4
520	1	7	7	1969	5
521	1	7	8	1969	1
522	1	7	8	1969	2
523	1	7	8	1969	3
524	1	7	8	1969	4
525	1	7	8	1969	5
526	1	7	10	1969	1
527	1	7	10	1969	2
528	1	7	10	1969	3
529	1	7	10	1969	4
530	1	7	10	1969	5
531	1	7	1	1970	1
532	1	7	1	1970	2
533	1	7	1	1970	3
534	1	7	1	1970	4
535	1	7	1	1970	5
536	1	8	4	1970	1
537	1	8	4	1970	2
538	1	8	4	1970	3
539	1	8	4	1970	4
540	1	8	4	1970	5
541	1	8	5	1970	1
542	1	8	5	1970	2
543	1	8	5	1970	3
544	1	8	5	1970	4
545	1	8	5	1970	5
546	1	8	6	1970	1
547	1	8	6	1970	2
548	1	8	6	1970	3
549	1	8	6	1970	4
550	1	8	6	1970	5
551	1	9	3	1971	1
552	1	9	3	1971	2
553	1	9	3	1971	3
554	1	9	3	1971	4
555	1	9	3	1971	5
556	1	9	5	1971	1
557	1	9	5	1971	2
558	1	9	5	1971	3
559	1	9	5	1971	4
560	1	9	5	1971	5
561	1	11	7	1977	1
562	1	11	7	1977	2
563	1	11	7	1977	3
564	1	11	7	1977	4
565	1	11	7	1977	5
566	1	11	8	1977	1
567	1	11	8	1977	2
568	1	11	8	1977	3
569	1	11	8	1977	4
570	1	11	8	1977	5
571	1	11	9	1977	1
572	1	11	9	1977	2
573	1	11	9	1977	3
574	1	11	9	1977	4
575	1	11	9	1977	5
576	1	11	10	1977	1
577	1	11	10	1977	2
578	1	11	10	1977	3
579	1	11	10	1977	4
580	1	11	10	1977	5
581	1	11	11	1977	1
582	1	11	11	1977	2
583	1	11	11	1977	3
584	1	11	11	1977	4
585	1	11	11	1977	5
586	1	11	12	1977	1
587	1	11	12	1977	2
588	1	11	12	1977	3
589	1	11	12	1977	4
590	1	11	12	1977	5
591	1	11	1	1978	1
592	1	11	1	1978	2
593	1	11	1	1978	3
594	1	11	1	1978	4
595	1	11	1	1978	5
596	1	11	2	1978	1
597	1	11	2	1978	2
598	1	11	2	1978	3
599	1	11	2	1978	4
600	1	11	2	1978	5
601	1	11	3	1978	1
602	1	11	3	1978	2
603	1	11	3	1978	3
604	1	11	3	1978	4
605	1	11	3	1978	5
606	1	11	4	1978	1
607	1	11	4	1978	2
608	1	11	4	1978	3
609	1	11	4	1978	4
610	1	11	4	1978	5
611	1	11	5	1978	1
612	1	11	5	1978	2
613	1	11	5	1978	3
614	1	11	5	1978	4
615	1	11	5	1978	5

APPENDIX B


```
/JOB
T057,T152.
/READ,IDCES
FTN(R=1)
LABEL(TAPE1,VSN=A0558,PO=R,F=L,LB=KU,PW=VONDERH)
REWIND,TAPE1.
LGO.
DAYFILE,L=DYF.
REPLACE,DYF.
EXIT.
DAYFILE,L=DYF.
REPLACE,DYF.
/EOR
      PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1)
C
C    THIS PROGRAM BUFFERS (BINARY READ) IN THE EARTH RADIATION BUDGET DATA
C    FROM A MAGNETIC TAPE AND THEN CONVERTS THE DATA WITH A
C    SPECIFIED TRANSFORMATION TO OBTAIN THE ACTUAL DATA VALUES.
C
      COMMON /IRB/ ILB(6),IX(36,18)
      DIMENSION  X(36,18)
C
C    INITIALIZE TAPE UNIT NUMBER.
C
      IUNIT = 1
C
C    INITIALIZE COUNTER WHICH KEEPS TRACK OF RECORD NUMBER.
C
      IREC = 0
C
C    READ IN THE RECORD NUMBER OF THE FIELD ONE WANTS TO EXAMINE.
C
    2 READ(5,3)  NREC
    3 FORMAT(I3)
C
C    IF RECORD NUMBER READ IN IS ZERO THEN JOB PROCESSING STOPS.
C
      IF(NREC .EQ. 0)  STOP2
C
C    BUFFER IN ONE RECORD FROM TAPE (IUNIT).
C
    4 BUFFER IN(IUNIT,1)  (ILB(1),IX(36,18))
      IF(UNIT(IUNIT))  15,7,10
    7 PRINT 9, IUNIT
    9 FORMAT(5X,'HIT EOF ON TAPE ',I2)
      STOP7
   10 PRINT 11, IUNIT
   11 FORMAT(5X,'PARITY ERROR ENCOUNTER ON TAPE',I2)
      STOP10
   15 CONTINUE
      IREC = IREC + 1
C
C    IF THE CORRECT RECORD IS NOT ENCOUNTERED THEN RETURN TO '4'
C    TO BUFFER IN NEXT RECORD ON TAPE.
C
      IF(IREC .NE. NREC)  GO TO 4
C
C    CONVERT DATA READ IN FROM TAPE BACK TO ORIGINAL VALUE.
C
      DO 20  J=1,18
      DO 20  I=1,36
         X(I,J) = FLOAT(IX(I,J))/1000. - 1000.
   20 CONTINUE
C
C    PRINT DATA FIELDS OUT FOR I=1,16.
C
      PRINT 30
   30 FORMAT(1H1,10(/),5X,' DATA FIELD AS IT APPEARS ON TAPE')
      PRINT 40, ILB
   40 FORMAT(/,5X,'RN   = ',I6,/,5X,'LOA  = ',I6,/,5X,'SS   = ',I6,
     Z       /,5X,'MN   = ',I6,/,5X,'YEAR = ',I6,/,5X,'THE  = ',I6,/)
      PRINT 50, (I,I=1,16)
   50 FORMAT(1X,16(6X,I2),/)
      DO 60  J=1,18
         PRINT 70,  J,(IX(I,J),I=1,16)
   60 CONTINUE
   70 FORMAT(1X,I2,1X,16I8,/)
      PRINT 80
   80 FORMAT(1H1,10(/),5X,' DATA FIELD AFTER CONVERSION TO ACTUAL'
     Z ' VALUES')
      PRINT 40, ILB
      PRINT 50, (I,I=1,16)
      DO 90  J=1,18
         PRINT 100,  J,(X(I,J),I=1,16)
   90 CONTINUE
  100 FORMAT(1X,I2,1X,16F8.3,/)
      GO TO 2
      END
```

DATA FIELD AS IT APPEARS ON TAPE

RN = 1
LOA = 1
SS = 3
MN = 7
YEAR = 1964
TOF = 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1174416	1181393	1181393	1174416	1174416	1174416	1181393	1181393	1181393	1188369	1188369	1188369	1188369	1188369	1188369	1188369
2	1181393	1181393	1181393	1181393	1188369	1188369	1188369	1188369	1188369	1188369	1188369	1188369	1195346	1195346	1195346	1195346
3	1195346	1195346	1195346	1195346	1202323	1209299	1202323	1202323	1202323	1202323	1202323	1209299	1209299	1209299	1209299	1209299
4	1195346	1202323	1195346	1202323	1209299	1202323	1209299	1216276	1209299	1216276	1216276	1223253	1230229	1223253	1230229	1230229
5	1202323	1202323	1195346	1216276	1216276	1202323	1216276	1216276	1216276	1223253	1223253	1244183	1258136	1258136	1265113	1258136
6	1223253	1216276	1223253	1230229	1223253	1230229	1223253	1209299	1195346	1202323	1216276	1258136	1272089	1279066	1279066	1279066
7	1237206	1230229	1230229	1230229	1230229	1230229	1230229	1202323	1188369	1167439	1202323	1244183	1272089	1272089	1272089	1265113
8	1237206	1223253	1230229	1230229	1216276	1223253	1230229	1209299	1188369	1174416	1181393	1216276	1251159	1251159	1230229	1216276
9	1244183	1237206	1230229	1230229	1230229	1223253	1223253	1209299	1181393	1174416	1181393	1202323	1237206	1251159	1230229	1209299
10	1265113	1244183	1237206	1244183	1251159	1251159	1244183	1237206	1202323	1195346	1209299	1209299	1237206	1265113	1258136	1251159
11	1258136	1258136	1258136	1258136	1272089	1279066	1272089	1265113	1244183	1237206	1244183	1244183	1258136	1272089	1272089	1265113
12	1251159	1251159	1258136	1258136	1265113	1258136	1265113	1258136	1251159	1251159	1258136	1251159	1258136	1265113	1265113	1258136
13	1223253	1223253	1223253	1230229	1230229	1230229	1223253	1230229	1223253	1223253	1237206	1230229	1237206	1244183	1237206	1230229
14	1188369	1195346	1195346	1202323	1202323	1202323	1188369	1195346	1195346	1188369	1195346	1195346	1195346	1195346	1195346	1188369
15	1174416	1174416	1174416	1174416	1181393	1174416	1167439	1160463	1167439	1160463	1167439	1160463	1167439	1160463	1160463	1167439
16	1146509	1139533	1139533	1139533	1125579	1125579	1125579	1111626	1118603	1118603	1118603	1125579	1125579	1132556	1132556	1125579
17	1125579	1118603	1111626	1104649	1097673	1090696	1083719	1076743	1076743	1076743	1076743	1076743	1083719	1083719	1076743	1083719
18	1104649	1104649	1097673	1097673	1090696	1090696	1076743	1076743	1069766	1069766	1069766	1069766	1069766	1069766	1069766	1062789

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DATA FIELD AFTER CONVERSION TO ACTUAL VALUES

RN = 1
LOA = 1
SS = 3
MN = 7
YEAR = 1964
TOF = 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	174.416	181.393	181.393	174.416	174.416	174.416	181.393	181.393	181.393	188.369	188.369	188.369	188.369	188.369	188.369	188.369
2	181.393	181.393	181.393	181.393	188.369	188.369	188.369	188.369	188.369	188.369	188.369	188.369	195.346	195.346	195.346	195.346
3	195.346	195.346	195.346	195.346	202.323	209.299	202.323	202.323	202.323	202.323	202.323	209.299	209.299	209.299	209.299	209.299
4	195.346	202.323	195.346	202.323	209.299	202.323	209.299	216.276	209.299	216.276	216.276	223.253	230.229	223.253	230.229	230.229
5	202.323	202.323	195.346	216.276	216.276	202.323	216.276	216.276	216.276	223.253	223.253	244.183	258.136	258.136	265.113	258.136
6	223.253	216.276	223.253	230.229	223.253	230.229	223.253	209.299	195.346	202.323	216.276	258.136	272.089	279.066	279.066	279.066
7	237.206	230.229	230.229	230.229	230.229	230.229	230.229	202.323	188.369	167.439	202.323	244.183	272.089	272.089	272.089	265.113
8	237.206	223.253	230.229	230.229	216.276	223.253	230.229	209.299	188.369	174.416	181.393	216.276	251.159	251.159	230.229	216.276
9	244.183	237.206	230.229	230.229	230.229	223.253	223.253	209.299	181.393	174.416	181.393	202.323	237.206	251.159	230.229	209.299
10	265.113	244.183	237.206	244.183	251.159	251.159	244.183	237.206	202.323	195.346	209.299	209.299	237.206	265.113	258.136	251.159
11	258.136	258.136	258.136	258.136	272.089	279.066	272.089	265.113	244.183	237.206	244.183	244.183	258.136	272.089	272.089	265.113
12	251.159	251.159	258.136	258.136	265.113	258.136	265.113	258.136	251.159	251.159	258.136	251.159	258.136	265.113	265.113	258.136
13	223.253	223.253	223.253	230.229	230.229	230.229	223.253	230.229	223.253	223.253	237.206	230.229	237.206	244.183	237.206	230.229
14	188.369	195.346	195.346	202.323	202.323	202.323	188.369	195.346	195.346	188.369	195.346	195.346	195.346	195.346	195.346	188.369
15	174.416	174.416	174.416	174.416	181.393	174.416	167.439	160.463	167.439	160.463	167.439	160.463	167.439	160.463	160.463	167.439
16	146.509	139.533	139.533	139.533	125.579	125.579	125.579	111.626	118.603	118.603	118.603	125.579	125.579	132.556	132.556	125.579
17	125.579	118.603	111.626	104.649	97.673	90.696	83.719	76.743	76.743	76.743	76.743	76.743	83.719	83.719	76.743	83.719
18	104.649	104.649	97.673	97.673	90.696	90.696	76.743	76.743	69.766	69.766	69.766	69.766	69.766	69.766	69.766	62.789

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APPENDIX 2

The following sections provide information about other reports sponsored in whole or in part by Contract NAG-1-150. (Contact the Department of Atmospheric Science, Colorado State University, Fort Collins, CO 80523 for copies.)

Appendix 2-1

Outline for

"Analysis Of NIMBUS-6 And NIMBUS-7 Data As It Pertains To The Earth Radiation Budget (ERB)"

by

Paul Ciesielski, Tom Vonder Haar,
Garrett Campbell (NCAR), and David Randel

Department of Atmospheric Science Paper No. 364, 1983
Colorado State University
Fort Collins, CO 80523

1.0 Introduction

2.0 Updated earth radiation budget data from NIMBUS-6

2.1 Zonal and global averages

2.2 Interannual variability in ERB

2.3 Normalization of zonal averages

2.4 NOAA SR data compared to NIMBUS-6 data for same time period

3.0 ERB analysis from NIMBSU-7

3.1 Our resolution enhancement scheme vs. conventional analysis (distance squared correction)

Appendix 2-2

Abstract

for

"Short-term Climatic Fluctuations Forced by Thermal Anomalies"

by

Adel Hanna

Department of Atmospheric Science Paper No. 360, 1982
Colorado State University
Fort Collins, CO 80523

The aim of this research is to study the response of the atmosphere to thermal anomalies using a low-order spectral model. Thermal anomaly patterns may exist either in sea and land surface temperatures or in the tropospheric diabatic heating.

A two-level, global, spectral model using pressure as a vertical coordinate has been developed. The system of equations describing the model is nonlinear and quasi-geostrophic (linear balance). Static stability is variable in the model. A moisture budget is calculated in the lower layer only. Convective adjustment is used to avoid supercritical temperature lapse rates. The mechanical forcing of topography is introduced as a vertical velocity at the lower boundary. Solar forcing is specified assuming

a daily mean zenith angle. The differential diabatic heating between land and sea is parameterized. On land- and sea-ice surfaces, a steady state thermal energy equation is solved to calculate the surface temperature. On the oceans, the sea surface temperature is specified as the climatological average for January. The model is used to simulate the January, February and March circulations.

Experiments are designed to study the response of the atmosphere to thermal anomalies at the lower boundary or in the midtroposphere. The "memory" in the atmosphere of such anomalies, after they have decayed, is also studied. Three patterns of sea-surface temperature anomalies are tested. The first pattern represents a cold anomaly in the North Pacific, the second a warm anomaly in the equatorial Pacific and the third pattern contains both of the two anomaly patterns acting together. The results suggest that the coupled pattern is the only one that produces the type of geopotential anomalies associated with the negative phase of the Southern Oscillation. In contrast to the results of linear models, warm sea-surface temperature anomalies in the equatorial Pacific cannot produce such geopotential response on their own. In the case of this tropical anomaly pattern the variance of temperature resulting from transient eddies tends to increase, whereas in the case of the coupled anomaly pattern the variance of temperature resulting from stationary eddies increases. This behavior suggests that with both anomalies acting together the atmosphere is inclined to produce quasi-permanent responses, such as blocking, in contrast with the other case, in which the transient activity increases.

The mid-tropospheric anomaly is introduced as an easterly propagating wave over the equatorial Pacific and over the Gulf of Bengal. The amplitude and memory of the response is larger than for the sea-surface temperature case. The mid-tropospheric thermal anomalies show continuous large areas of long memory in the subtropical and middle latitude regions of the Northern Hemisphere.